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This research is concerned with perception and memory of pictures. The theoretical motivation behind the experiments vary from area to area: in some cases, we want to test predictions of a connectionist model for picture recognition; in others we want to compare pictures with words to determine whether the two surface forms are understood at the same rate; in still others, the pictures are used as a vehicle to study questions about implicit memory.

Although there are five areas of research, here I will mention highlights from only two. In the area of perception, interference in identification of a degraded image occurs when even more degraded images of the same object precedeit. We tested, and rejected, the explanation proposed by Bruner and Potter that erroneous hypotheses about the object's identit interfere with subsequent recognition in favor of the explanation generated by our connectionist model. This explanation holds that transient activation of perceptual features common to the target and its distractors reduces the signal-to-noise ratio and causes interference. We were able to eliminate interference by having subj ts solve math problems betwee presentations of the more degraded images

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19. (continued) In the area of implicit memory, we found that the best priming stimulus for subsequent identification was a moderately fragmented, as compared to a very fragmented or almost complete stimulus. We developed the perceptual closure hypothesis to account for this effect -- it says that the more difficult perceptual closure or completion of the fragmented figure is to achieve, the more priming occurs, as along as closure is finally achieved.

PERCEPTION AND MEMORY OF PICTURES
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Attachments

Hirshman, E., Snodgrass, J. G., Mindes, J., & Feenan, K. (1990). Conceptual priming in picture fragment completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 634-647.

Snodgrass, J. G., & Feenan, K. (1990). Priming effects in picture fragment completion: Support for the perceptual closure hypothesis. *Journal of Experimental Psychology: General, 119*, 276-296.

Snodgrass, J. G., & Hirshman, E. (1991). Theoretical explorations of the Bruner-Potter (1964) interference effect. *Journal of Memory and Language, 30*, 273-293.

Snodgrass, J. G., & Poster, M. (1991). Visual word recognition thresholds for screen-fragmented names of the Snodgrass and Vanderwart pictures. *Behavior Research Methods, Instruments, and Computers*, In press.

Abstract

This research is concerned with perception and memory of pictures. The theoretical motivations behind the experiments vary from area to area: in some cases, we want to test predictions of a connectionist model for picture recognition; in others we want to compare pictures with words to determine whether the two surface forms are understood at the same rate; in still others, the pictures are used as a vehicle to study questions about implicit memory.

Although there are five areas of research, here I will mention highlights from only two. In the area of perception, interference in identification of a degraded image occurs when even more degraded images of the same object precede it. We tested, and rejected, the explanation proposed by Bruner and Potter that erroneous hypotheses about the object's identity interfere with subsequent recognition in favor of the explanation generated by our connectionist model. This explanation holds that transient activation of perceptual features common to the target and its distractors reduces the signal-to-noise ratio and causes interference. We were able to eliminate interference by having subjects solve math problems between presentations of the more degraded images. In the area of implicit memory, we found that the best priming stimulus for subsequent identification was a moderately fragmented stimulus, as compared to a very fragmented or almost complete stimulus. We developed the perceptual closure hypothesis to account for this effect -- it says that the more difficult perceptual closure or completion of the fragmented figure is to achieve, the more priming occurs, as along as closure is finally achieved.

PERCEPTION AND MEMORY OF PICTURES

Research Objectives

This research project is concerned with perception and memory of pictures. The areas of research are linked by the assumption that perceptual acts produce memorial consequences. These consequences can be assessed by both implicit and explicit memory tasks. Accordingly, the research is concerned with performance on perceptual tasks, and the relationship between that performance and performance on tests of implicit and explicit memory. A connectionist model of picture recognition which was developed and tested in collaboration with Elliot Hirshman provides a unifying framework for the research and testable hypotheses for how the system works.

Fragmented Word Norms

Because comparisons between pictures and words have become increasingly important in all the areas of research, we developed a method of fragmenting words so as to produce comparable fragmented stimuli for words to those developed by us for pictures. The words were fragmented in the same manner as the pictures, to produce a stimulus fragmented at 8 levels of completion, with two differences: First, because the words were more compact than the pictures, the size of the pixel block used for deletion for words was an 8x8 pixel square in contrast to the 16x16 pixel square used for pictures. Second, the exponential rate parameter for words was set at 0.85 in contrast to the rate parameter for pictures, which had been set at 0.70. This meant that words at each level of completion had more pixel blocks exposed than did pictures.

We collected identification thresholds for fragmented words which were the names of the Snodgrass and Vanderwart (1980) pictures. Thresholds for 250 picture names were measured for two groups of 20 subjects, who each saw half of the words. The threshold was measured by presenting each word with the ascending method of limits (most fragmented level first), and terminating the series when the subject's typed response corresponded exactly to the target word. The threshold was the level of fragmentation at which correct identification took place. During the ascending trials, subjects had the option to hit return, thereby registering a blank, if they had not idea what the word was; otherwise they were encouraged to guess. All blanks and guesses were recorded. This project was carried out as an MA thesis project by Meredith Poster, and the norms for the words have been published (Snodgrass & Poster, 1991).

We also explored whether three variables --frequency in print, word length, and neighborhood size -- had any effect on word thresholds. Neighborhood size, N, is the number of different English words that can be produced by changing just one of the letters, preserving letter positions (Coltheart, Davelaar, Jonasson, & Besner, 1977). None of the three variables predicted performance. We were particularly puzzled by the lack of an effect of neighborhood size because on logical grounds, we expected that a word with many neighbors would suffer from interference. We reasoned that words with many neighbors might produce erroneous guesses while words with few neighbors might produce blanks. We found that although the item-based correlation (Pearson *r*) between overall threshold (a direct measure of total errors per item) and neighborhood size was an insignificant -.11, when total errors were divided into guesses and blanks, the correlation between neighborhood size and absolute number of guesses was significant and positive ($r = +.26$), and the correlation between neighborhood size and absolute number of blanks was significant and negative ($r = -.25$). The correlations were even higher (+.49 and -.49 respectively) when relative rather than absolute values were used.

Furthermore, the pattern of errors in guesses which matched the target word in length closely followed the serial position function of neighborhood size (that is, the number of words which can be formed by changing the first, second, third, etc. letter of the word). These functions in turn closely followed the probability that the word contained a consonant rather than a vowel at that serial position.

Figure 1 below shows a comparison of consonant probability functions, neighborhood serial position functions, and error serial position functions for 4-letter words. All values have been normalized so that their sum across serial positions equals 1.0.

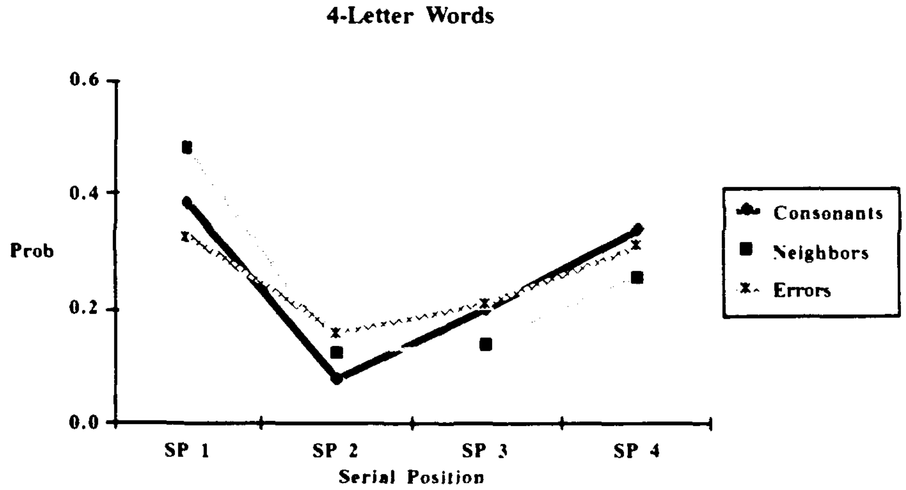

Figure 1. Errors compared to neighborhood size and consonant probability at each serial position for four-letter names of the Snodgrass and Vanderwart pictures.

As shown above, the serial position function for errors in guesses closely follows the neighborhood size serial position function, which in turn closely follows the consonant probability serial position function. In short, subjects tend to guess at words with large neighborhoods, these guesses tend to contain errors at positions in the word having the largest neighborhoods, and these large neighborhoods tend to be at positions within the word containing consonants.

Our findings indicate that while neighborhood size may not be reflected in overall performance measures such as item thresholds, neighborhood size does affect the type of error (blank or guess) subjects make and the location of errors within guesses. In order to follow up these serendipitous findings, we designed a second experiment to investigate the joint effect of frequency and neighborhood size in a more controlled manner. Although in that experiment, both frequency and neighborhood size were positively related to identification thresholds, the effects of neighborhood size observed in the first experiment were replicated. Specifically, much larger effects of neighborhood size were observed in determining whether an error would be a guess or a blank and in determining the serial position of an error in a guess. A detailed report on these neighborhood size effects is in the process of being prepared for publication (Snodgrass, 1991).

Although this extensive exploration of neighborhood size effects in word fragment identification falls outside the specific areas of research proposed by this grantee, these neighborhood size effects would appear to support connectionist models of word recognition in general, and the Hirshman-Snodgrass model of picture and word recognition in particular, and so are very relevant to an important theoretical motivation for the present grant research.

The strongest competitors to connectionist models of word recognition are the serial search models of lexical access, particular that proposed by Forster (1976, 1987). Serial search models predict that neighborhood size should always inhibit word recognition (in contrast to the results found in Experiment 2 above and to a number of other results in the literature). Connectionist models, on the other hand, can accommodate both inhibitory and facilitory effects of neighborhood size. In particular, a connectionist model can easily account for the different rates of occurrence of errors and blanks for words with small and large neighborhoods. Activation of features for a target with no neighbors which is not sufficient to pass the target's recognition criterion will not pass any item's recognition criterion, and so the subject will respond with a blank. Activation of features for a target with many neighbors may cause a neighbor to exceed its recognition threshold when the target fails to do so, particularly when the neighbor is of higher frequency than the target and thus requires less evidence for activation. In this case, the subject will generate an erroneous hypothesis about what the target is and will respond with a guess. Although we have not yet simulated these neighborhood effects with our word recognition model, we plan to do so in the near future.

Perceptual Tasks

Three perceptual tasks were studied. In the first, information was limited by using fragmented images, and the interference produced by preceding the fragmented image with more degraded images was studied. In the second, information was limited by presenting intact images in rapid visual serial presentation (RSVP), and performance in identifying a target stimulus from among a rapid series of images for pictures was compared to words. In the third, semantic priming in classification of pictures and words was studied by varying the nature of the prime word preceding the target.

1. Interference in perceptual identification of fragmented pictures.

Prior presentation of a portion of a target's perceptual features inhibit its subsequent recognition. This effect was first demonstrated by Bruner and Potter (1964) who showed that identification of objects which were gradually brought into focus became progressively worse as initial levels were made more blurred. They attributed this interference effect to subjects' erroneous hypotheses about the object which interfered with correct perception.

In the present research, we generated interference by preceding a moderately fragmented (level 4) picture with more fragmented levels (levels 1, 2, and 3) in an ascending method of limits procedure. This interference or ascending condition was compared to a fixed or control condition in which only a level 4 picture was presented. In a series of five experiments reported in Snodgrass and Hirshman (1991), we tested a number of different hypotheses about the source of the interference. We tested Bruner and Potter's erroneous hypothesis explanation by forcing subjects to generate guesses at each level of the ascending condition, and either giving subjects feedback for correctness (feedback condition) or not (no feedback condition). We found, contrary to the predictions of the erroneous hypothesis explanation, that feedback did not diminish the interference effect.

The Hirshman/Snodgrass connectionist model showed the interference effect in a simulation but did so by producing greater transient activation in features common to target and distractor items in the ascending than fixed condition, thereby reducing the signal-to-noise ratio. In an experiment designed to test the transient activation explanation, we attempted to reduce the activation in the ascending condition by having subjects solve math problems between trials in the ascending condition. We reasoned that this manipulation would reduce activation levels in the distractor items by both the delay and the removal of the fragment. We found, as predicted, that the math condition eliminated the interference effect.

In subsequent experiments, we followed up results reported by Peynircioglu and Watkins (1986) who found similar interference effects in word fragment completion, but only for studied items. In a series of four experiments, we compared interference for studied vs. nonstudied items and were able to replicate their results with only limited success. The first two experiments used fragmented pictures. In the first experiment, the interference effect was equally large for both studied and unstudied pictures; however, performance on the studied pictures was very high so the size of the interference effect may have been limited by ceiling effects. In the second experiment, in which performance levels were lower, both studied and unstudied pictures showed the interference effect, but the size of the effect for studied pictures was larger than for unstudied pictures.

The third and fourth experiments used fragmented words rather than fragmented pictures. In both experiments, subjects studied 30 almost complete (level 7) words during the priming phase, and were tested on 60 fragmented words at test. Half of the test items were old and half were new, and half were presented with the standard ascending method while the other half were presented with the fixed method. In the third experiment we exactly replicated, for the first time, the results of Peynircioglu and Watkins. We found a robust interference effect for studied words, but no interference effect for unstudied words. In the fourth experiment, there was no interference effect for either studied or unstudied words, but the overall level of performance was very low. The first three experiments used college student volunteers at New York University, while the fourth experiment was conducted by a high school student as part of her Westinghouse project and used high school student volunteers. The percentages of correct identifications in each of the four conditions for the last two experiments are shown in Table 1:

Table 1

Results of two experiments testing the interference effect for fragmented words

	Test Condition					
	Asc-Old	Fix-Old	Asc-New	Fix-New	Inter(Old)	Inter(New)
Exp 3 - College Students	58	73	45	44	15	-1
Exp 4 - High School Students	47	46	25	26	-1	1

As shown above, Experiment 3 replicated Peynircioglu and Watkins (1986) by showing a large interference effect for old items but no interference effect for new items. Experiment 4, on the other hand, showed interference effects for neither the old nor the new items. In addition, Experiment 4 yielded much lower performance than Experiment 3.

Our present hypothesis is that the interference effect is mediated by a level of performance variable -- performance must be fairly high (above 50%) to obtain the interference effect; if performance drops below a certain level, interference will not be obtained because the activation from lower levels than the target level is not high enough to cause interference. In order to test this prediction, we need to vary level of performance two ways: first by varying the study status of the items (because studied items produce higher levels of performance than unstudied items do), and second, by the varying the rate of completion of the items so as to vary the amount of information in the stimulus at level 4. Once this experiment is completed, we will be in a position to publish this research in the context of a coherent theoretical explanation.

In later papers, Peynircioglu (1987a,1987b) has drawn parallels between the interference effect in perception and the part-set cuing effect in free recall. In the part-set cuing effect, subjects given a subset of items from the recall list as retrieval cues do worse in recalling the remaining items than do subjects given no list items at all (Nickerson, 1984). This interference effect has been attributed to inefficient retrieval strategies imposed by the part-set cues. One of my graduate students, Chun Luo, has tested this hypothesis by varying the degree of inter-item association of the free recall list. His data confirmed that the part-set cuing effect was larger for unassociated than for associated lists, and that, indeed, for a list with very high inter-item association, interference from part-set cuing disappeared altogether. His explanation for the effect is similar to that proposed by Raijmakers and Shiffrin (1981) in the SAM model of memory: Items from unassociated lists become associated to the context of the experiment rather than to one another. So the most efficient retrieval cues for recall of items from unassociated lists are the context rather than the items themselves. Providing cues at test interferes with the subject's ability to use the context as a retrieval cue. In contrast, the most efficient retrieval cues for associated items in a recall list are other items. So providing cues at test for associated lists merely reinforces the subject's own natural retrieval strategy.

Luo has reported these results at meetings of the Eastern Psychological Association (Luo, 1991) and he has submitted the paper for publication.

2. Rapid visual serial presentation (RSVP) of pictures and words.

The question motivating this line of research is the following: Are pictures understood faster than their names? This question has generally been answered by comparing categorization speed for pictures versus their names. Because pictures are usually categorized faster than words, this fact has often been taken to mean that pictures are understood faster than words. This conclusion is based on the assumption that in order to categorize a picture -- to determine, for example, that it is an animal as opposed to a fruit -- it is necessary to access its meaning.

Snodgrass and McCullough (1986) have argued that categorization is not an ideal task to answer this question because pictures in such natural categories as animals and fruits tend to share visual features. Subjects can capitalize on the visual similarity among pictures within categories by using visual attributes such as four legs or roundness as a shortcut to classifying a picture as an animal or a fruit, thereby bypassing semantic access. Such a strategy could produce spuriously fast categorization times for pictures, but the same strategy could not work for words because there is no graphemic feature which distinguishes the *names* of animals from the *names* of fruits.

Instead, we chose to manipulate the speed with which concepts are presented and examine the differences in identification performance. We implemented an RSVP task on the Apple Macintosh microcomputer for comparing the speed of identification of pictures and words. In this procedure, subjects are presented with a rapid sequence of 16 pictures or words. A target stimulus within the sequence is accompanied by a distinctive visual or auditory cue, and the subject's task is to identify the item by pointing to the target in an array of list items (recognition response) or by typing the name of the target (recall response).

We have completed four experiments using the RSVP procedure. In the first experiment, we compared the performance of pictures to words when rates of presentation were very fast (10 to 15 items/second), lists were either from a mixture of categories (mixed list condition) or from the same category (pure list condition), and the subject's task was to report the name of the target (identified by a surrounding frame) by pointing to the name of the target in an array of list items (recognition response). For the mixed list condition, performance for pictures was equal to words but for the pure list condition, words were better than pictures (and pictures from pure lists were worse than pictures from mixed lists). We attributed the interference in the pure list pictures condition to visual similarity among pictures in the same category, leading to competition for visual feature detectors. The pure list condition puts pictures at a disadvantage for the same reason that the categorization task puts pictures at an advantage -- visual similarity among pictures within a category hinders the identification of a target item within a list of items from the same category. We argued that the fairest comparison between pictures and words was the mixed list condition, and that condition showed that pictures and words were understood at the same rate.

In a second experiment, we varied the rates of presentation over a wider range (7 - 20 items/second) and compared frame to boldface cues for mixed list pictures and words. In the boldface cue condition, the target word was printed in boldface and the target picture was outlined in heavier lines. In this experiment, pictures were better than words with frame cues, but words were better than pictures with boldface cues. It would appear that the cue used to signal the target item interacts with the surface form of the concept (pictorial or graphemic).

In a third experiment,we used the frame cue but this time with a recall rather than a recognition response (because of the possibility that subjects may have pattern-matched the target with the recognition responses rather than actually identified them). With this change in response mode, words were better than pictures, in contrast to Experiment 2 in which pictures were better than words with the frame cue. We believe that this is a compatibility effect -- words are easier to recall than pictures because words can be more quickly read than pictures can be named. This interpretation was supported by our finding that the advantage of words over pictures disappeared over the five days of the experiment, so that at the end, words and pictures were equivalent, although pictures never recovered the advantage they had with the recognition response. Thus response mode (recognition or recall) also interacted with stimulus form. Figure 2 below shows the improvement in probability of correct recall (PC) for pictures over the five days of the experiment:

LEARNING FOR PICTURES VS. WORDS, RECALL

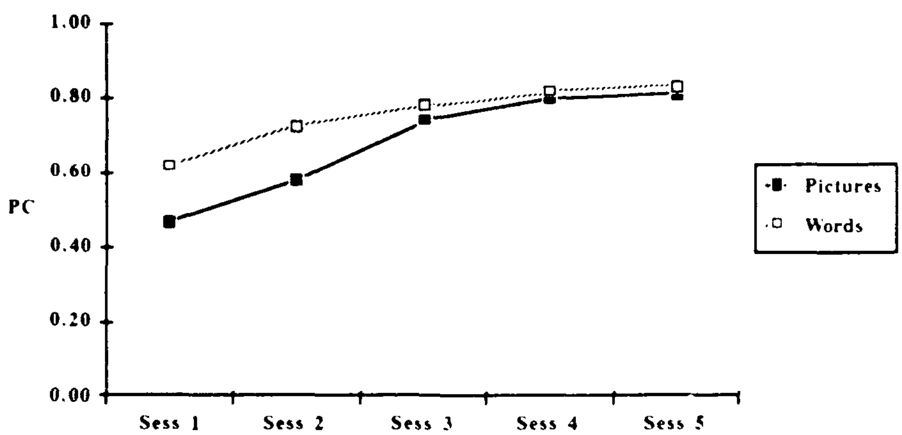

Figure 2. Improvement in recall of pictures as a function of practice for Experiment 3.

In considering the interaction between the type of cue and the surface form of the target, we thought that the frame cue might favor pictures because the frame was closer to the outline of the picture than the outline of the word, and the boldface cue might favor words because boldface words were more distinctive than boldface pictures.

In a fourth experiment we attempted to use a cue which would be neutral with respect to stimulus form by comparing a beep cue to both a frame and a boldface cue. In the beep cue condition, the target item was signaled by a beep occurring simultaneously with its presentation. In this experiment, we used the recognition rather than the recall response.

For the frame cue, the usual advantage of pictures over words was obtained, and for the boldface cue, the usual advantage of words over pictures was obtained. For the beep cue, words were better than pictures, although performance was considerably worse with the beep cue than with either the frame or the boldface cue, due presumably to the fact that subjects must divide attention between visual and auditory modalities. Figure 3 compares the performance of pictures to words under each cue. The only condition in which pictures are superior is with the frame cue. On the basis of all of these results, then, we conclude that if there are any differences between pictures and words in the speed of understanding, words have the advantage.

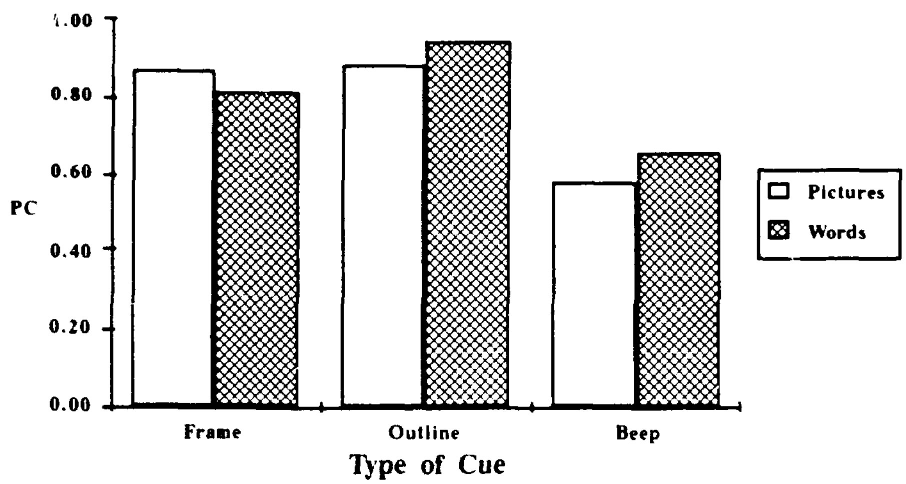

Figure 3. Comparison of performance for pictures and words under the three types of cues in Experiment 4.

These experiments were reported at the 1990 meetings of the Psychonomic Society in New Orleans in November (Snodgrass & Feenan, 1990) and they are in the process of being written up for publication (Feenan & Snodgrass, 1991).

3. Effects of short-term priming on categorization latencies.

In this research we attempted to replicate, for pictures, the short-term priming effects that have been observed in word recognition. The original motivation for these experiments came from the Hirshman and Gomes (1990) word recognition model, which in turn formed the basis of the Hirshman and Snodgrass picture recognition model. The Hirshman and Gomes model was developed to account for several results on semantic priming effects in word recognition. In the semantic priming paradigm, a target word is preceded by a prime which can be identical to the target, related to the target, unrelated to the target, or neutral (a string of X's) and the subject's task is either lexical decision (classifying the target as a word or nonword) or naming the target word. The amount of priming is measured by the speed up in decision time compared to the neutral condition. Researchers have found that identical primes facilitate recognition the most, semantically-related primes next most, and unrelated primes actually interfere with word recognition compared to the neutral condition.

Although we originally planned to use a naming task to replicate these effects for pictures, because we had not yet implemented a procedure for measuring naming latencies with the Macintosh microcomputer, we used a categorization task instead.

We carried out two short-term priming experiments in which the category decision was to classify the target item as natural or man-made. In Experiment 1, pictures were targets and they were preceded by word primes. In Experiment 2, both pictures and words were targets, and the primes were again words. In Experiment 1, three priming conditions were compared: identical, related, and unrelated primes. In Experiment 2, only two priming conditions -- related and unrelated primes, were used. In Experiment 1, the expected effects were obtained -- namely, identical primes produced faster responses than related primes, which in turn produced faster responses than unrelated primes (whether unrelated primes were inhibitory or not could not be determined because we did not run a neutral condition). In Experiment 2, unaccountably, related primes did not produce faster responses than unrelated primes, although pictures were classified faster than words.

These experiments were initially considered as pilot experiments, and were to be used to measure the relatedness of the prime-target pair under the reasonable assumption that the more related a prime is to a target, the more it will facilitate target classification. As part of his MA thesis, Robert Hagen measured prime-target relatedness in several additional ways, including free association to the prime and ratings of relatedness of the prime-target pair. We discovered that there was *zero* correlation between the ability of a prime to facilitate classification of its related target and these other measures of relatedness, even though the other measures intercorrelated with one another. This has led us to conclude that the" semantic"priming effect may not indicate a spread of activation from the prime to the target, as is the normal interpretation, but rather may simply bias the subject toward one of the two categories depending upon the category of the prime. These conclusions are similar to those of Neely, Keefe, and Ross (1989) for lexical decisions. These results were reported at the April, 1991 meetings of the Eastern Psychological Association (Snodgrass & Hagen, 1991), and are in the process of being written up for publication.

Memory Tasks

Two types of memory tasks -- implicit memory and explicit memory -- were explored. In implicit memory tasks, subjects study pictures or words and then are tested on their perceptual identification of pictures or words (using fragmented images and the ascending method of limits). Implicit (perceptual) memory is exhibited when subjects are able to better identify studied than unstudied items. In the literature this is known as a long-term priming paradigm, in which the studied items "prime" or facilitate the identification of the same items during the test.

In explicit memory tasks, in contrast, subjects study pictures or words and then are tested on their ability to explicitly remember whether they saw the item previously. Our typical explicit test is recognition memory, in which the subject is presented with the item again and asked to make an old/new judgment about it.

1. Implicit memory.

We have explored a number of variations in implicit memory, varying the degree to which the task is based upon perceptual compared to semantic processing. This is accomplished by comparing within-form priming (pictures at study, pictures at test) with cross-form priming (words at study, pictures at test). In a series of recent within-form experiments (Snodgrass & Feenan, 1990),we found that while within-form priming can be obtained under a wide variety of conditions, more priming occurred for moderately fragmented pictures at study than for either very fragmented or very complete stimuli. The mechanism we proposed to account for this phenomenon was perceptual closure: the more difficult perceptual closure or completion of the fragmented figure is to achieve, the more priming occurs, as long as closure is finally achieved.

In a second series of experiments, using cross-form priming, we found that generating a word to a sentence frame primed identification of the picture corresponding to that word while merely reading the word did not. We (Hirshman, Snodgrass, Mindes, & Feenan, 1990) proposed that the generation effect which produced perceptual priming in implicit memory tasks was different from the generation effect which produces higher levels of recall in explicit memory tasks, in that the former is not mediated by explicit memory for the generation response. Rather, we believe that priming effects are mediated by both perceptual processes (as in the within-form priming experiments) and conceptual processes (as in the cross-form priming experiments in which generating the item provides sufficient conceptual processing for priming to occur).

This conceptualization of long-term priming has led us, in research contained in our latest research proposal to this agency, to design experiments to provide quantitative estimates of the effects of semantic and visual processing on later perception in the experimental paradigm used by Hirshman et al. (1990). In doing this we hope to introduce a general method that can be used to estimate the relative importance of visual and semantic processing in other experimental paradigms.

2. Explicit memory.

a. Continuous recognition memory. We implemented two experiments in continuous recognition memory to test a prediction of our connectionist model of picture recognition.

This experiment was motivated by a set of results on continuous recognition memory I reported several years ago (Snodgrass, 1988), in which both hit and miss RTs increased with lag (the number of items between the first and second presentation of an item). Although virtually any model of recognition memory predicts that hit latencies will increase with lag, most models of recognition memory cannot predict the increase in miss latencies with lag. Our connectionist model of picture recognition predicts this result quite naturally. It does so by using a fairly primitive mechanism for making decisions about whether an item is old (has been seen before) or new (has not been seen before). Specifically, the number of cycles required for a target item to attain criterial activation (be recognized) will vary as a function of a number of factors, including whether the item has been seen before or not, and how recently. Because old items will be recognized faster than new items, the system could use the number of cycles required for recognition as a criteria for deciding whether an item was old or new. The number of cycles to recognition in turn is a natural measure of what Jacoby and Dallas (1987) called perceptual fluency -- the speed with which an item can be recognized. Thus the model has a natural mechanism for conferring perceptual fluency on a previously-seen item, and several researchers have suggested that perceptual fluency may form one basis of a recognition memory decision (Gardiner & Java, 1990; Jacoby & Dallas, 1981; Mandler, 1980).

For old items which vary in lag, the model predicts that the number of cycles required for recognition is a monotonically increasing function of lag. So the model predicts that both hit and miss latencies will increase with lag because memory strength decreases with lag. To appreciate this relationship, consider the distributions of number of cycles to recognition for old items at two lags (0 and 20) shown in Figure 4.

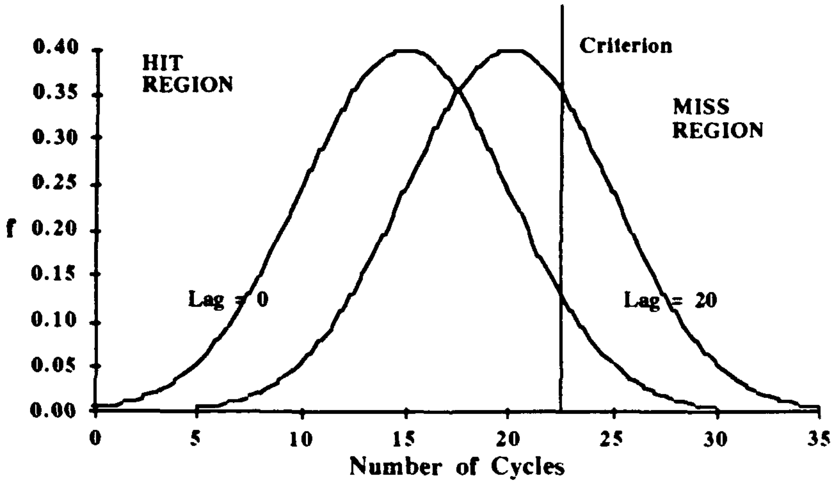

Figure 4. Distributions of number of cycles for a recently presented (lag = 0) and a remotely presented (lag = 20) stimulus. When the number of cycles falls below the criterion, the subject responds *Yes* and hits the target, and when the number of cycles exceeds the criterion, the subject responds *No* and misses the target.

The distributions of number of cycles to recognition have been assumed normal and truncated at ±3 SD. The average speed for hits and misses under the two lags is obtained by computing the average cycles for areas to the left and right of the criteria respectively. When this is done, the ordering of the mean number of cycles to criterion (and hence of the RTs) is: Hit (lag 0) < Hit (lag 20) < Miss (lag 0) < Miss (lag 20), which gives the correct empirical ordering of hit and miss latencies found by Snodgrass (1988).

It is important, in testing this prediction, to minimize the role of semantics in the recognition memory decision and maximize the role of perceptual appearance. Accordingly, we used moderately fragmented and very fragmented pictures as stimuli. The moderately and very fragmented pictures corresponded to the level of image degradation at which 35% and 10% of the subjects could identify a given picture, respectively, according to the Snodgrass and Corwin (1988) norms.

Two experiments were carried out. In the first, 16 subjects participated in one session of a continuous recognition memory task, and in the second, six subjects participated in six sessions each.

Each session consisted of a series of 300 trials in which target stimuli were repeated after lags of 5, 10, and 20 items. Subjects were instructed to decide whether a stimulus was old or not by pressing a *Yes* or *No* key as quickly as possible and with their first impulse. The pictures were fragmented so as to both increase the error rates (so error latencies could be measured reliably) and to make subjects rely more on visual appearance and less on meaning.

The qualitative results of both experiments were in general agreement with the model -- both hit and miss RTs increased with lag, and the longest hit RT was shorter than the shortest miss RT. Furthermore, both hit and fal: : :larm RTs were faster than correct rejection RTs.

We also tried to fit the model to the data from Experiment 1 quantitatively. Here, the model failed to fit the quantitative results, primarily because the model predicts that all *No* responses should be much longer than they are because a No response only occurs when the perception time for a stimulus takes so long that it falls above the old/new criterion. Figure 5 shows the fit of the model for the 35th percentile condition when the basetimes were set to zero so that all the differences in RT were attributed to differences in recognition times:

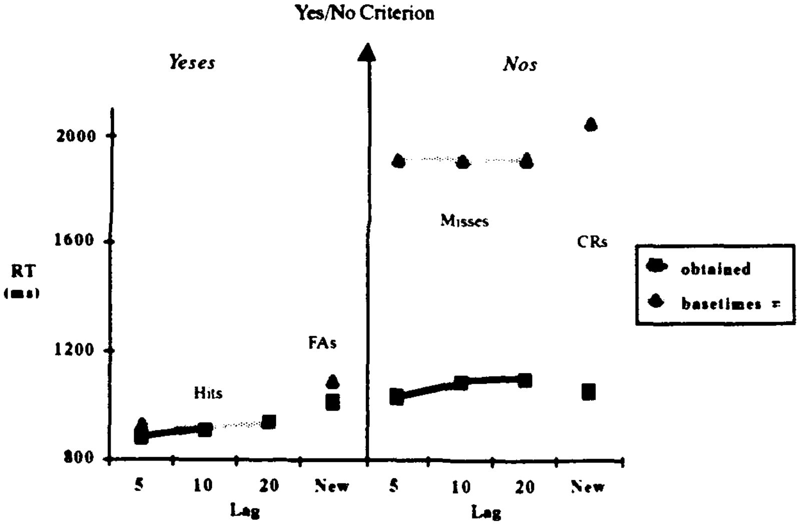

Figure 5. Predicted (triangles) and obtained (squares) RTs for the continuous recognition memory experiment under the assumption that basetimes for both responses are zero.

As Figure 5 shows, if it is assumed that the basetimes for old and new responses are zero (to maximize the lag effect) then the model predicts that *Nos* should be much longer than *Yeses* because *No* responses only occur when the perceptual speed is slower than the criterion. The observed data clearly show that there is a smaller than predicted overall difference between *Yeses* and *Nos*. And even with basetimes set to zero, the model underpredicts the lag effect.

In order to predict *Yes* and *No* responses better, we tried adjusting the basetimes of *Nos* to be faster than basetimes of *Yeses*. In the fits shown in Figure 6, the basetime for *Yeses* was set to 510 ms and the basetimes for *Nos* to 150 ms.

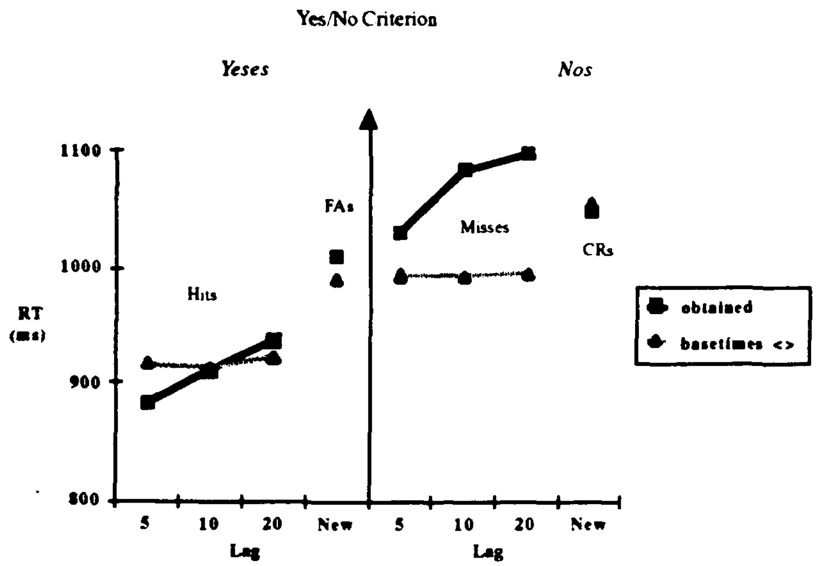

Figure 6. Predicted (triangles) and obtained (squares) RTs for the continuous recognition memory experiment under the assumption that basetimes for both responses are unequal.

Here, although the differences between *Yeses* and *Nos* are better predicted, the lag effects are now even more severely underpredicted.

In summary, although this model can account for certain qualitative effects in the data, such as the increase in miss latencies with lag, which other models fail to account for, it fails to generate correct quantitative predictions. One can imagine several ways in which the model could be modified. For example, it is possible that only a proportion of decisions are based upon fluency and the rest on retrieval of a specific episode. This modification in the model would make it very similar to the two-factor model that Atkinson and Juola (1974) have proposed for recognition memory. In their model, familiarity is used as the basis for some old/new decisions (those at the extremes of the familiarity continuum), while items having intermediate values of familiarity undergo a more extensive serial search.

Another possibility for modifying the model is to retain the assumption that all decisions are based upon fluency, but to assume that subjects impose a time deadline such that if a stimulus has not been recognized in a certain number of cycles, the wait is terminated and the system defaults to a *No* response. This modification in the model leads to the prediction that the effect of lag will be more pronounced on hit than on miss latencies, an effect which is readily apparent in the data.

This research is being conducted in collaboration with David Fendrich who was a postdoctoral fellow with me during the first year of the grant, and is presently an Assistant Professor at Widener University. We are continuing this line of research because as far as we know, the connectionist model with perception time as a criterion for old/new decisions is the only model of recognition memory which correctly predicts that miss latencies will increase with lag.

b. Fluency effects in recognition memory. The second set of experiments follow directly from the model described above for continuous recognition memory. To the extent that recognition memory decisions can be based upon perceptual fluency, we should observe similar effects on recognition memory performance (errors and latencies) that are observed in perceptual identification. Specifically, classes of stimuli which are easily identified after a priming experience should also, because of their perceptual fluency, be easily recognized as old.

To test this, we carried out three experiments in which the level of fragmentation of the study stimulus was varied. In our previous research, we found that a moderately fragmented (level 4) stimulus produced more priming in perceptual identification than either a very fragmented (level 1) or an almost complete (level 7) stimulus (Snodgrass & Feenan, 1990). Our expectation, then, was that a moderately fragmented stimulus would also be better recognized in a Yes/No recognition test.

One complication in designing these experiments was deciding which level of stimulus should be presented in the recognition test. In the identification test, which typically uses the ascending method of limits, the most fragmented stimulus is presented first, followed by increasingly more complete levels until the stimulus is identified. In the usual recognition test, in contrast, a complete stimulus is usually presented. The problem with using a complete (level 8) stimulus in the recognition test is that this confounds to some extent the similarity between the priming level and the recognition level. Across the three experiments, we varied the level of fragmentation of the study stimulus and the level of fragmentation of the recognition test stimulus to attempt to separate effects of priming level from prime-test compatibility.

In Experiment 1, we used the same priming levels used by Snodgrass and Feenan (1990) in their study phase, namely levels 1, 4, and 7. During the study phase, subjects saw a total of 30 pictures, 10 at each of the three levels of fragmentation. The recognition test followed the study phase and the perceptual identification test followed the recognition test. Each test was preceded by a brief distractor task consisting of an unrelated visual discrimination task.

The recognition test used complete pictures (level 8) and the perceptual identification test used moderately fragmented (level 3) pictures. In order to encourage subjects to use fluency as the basis for their recognition judgment, they were instructed to respond as quickly as possible, and with their first reaction.

Contrary to our expectations, there was no relationship between perceptual identification performance and recognition performance. Figure 7 shows perceptual identification accuracy compared to both recognition accuracy and speed. All functions are shown as a percentage of range. RTs have been converted to speed measures so that high values will mean good performance.

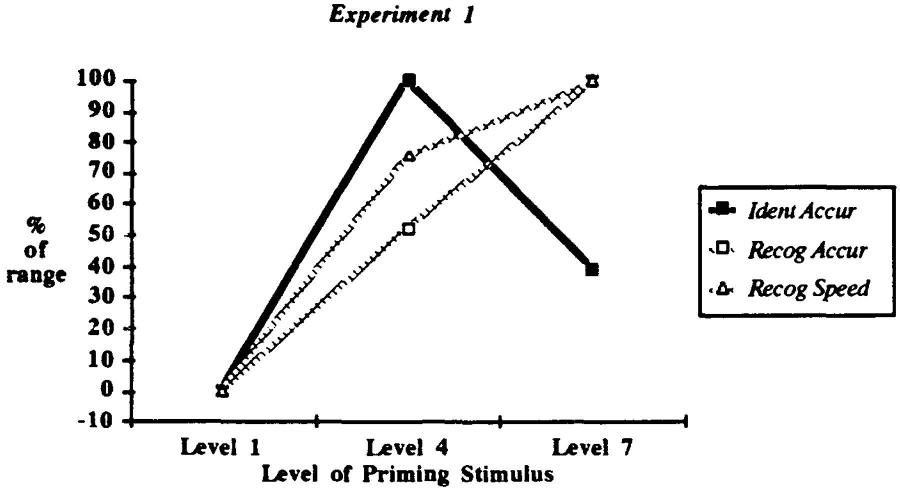

Figure 7. Three measures of performance as a function of priming level for Experiment 1.

Although the perceptual identification results show the usual inverted U-shaped function we found previously, the recognition results consistently show superiority for the most complete (level 7) priming stimulus.

One possible explanation for the results of Experiment 1 is the compatibility explanation for dissociations between implicit and explicit memory tasks proposed by Roediger and his colleagues (Roediger & Blaxton, 1987; Roediger, Weldon, & Challis, 1989; Weldon & Roediger, 1987). [Although Roediger calls this *transfer appropriate processing*, I have adopted the pithier term *compatibility* introduced by Hintzman (1990) in his review of this literature.] According to the compatibility hypothesis, a study episode will transfer to a test episode to the extent that the processes engaged by the study stimulus are the same as the processes engaged by the test stimulus.

Under this hypothesis, perceptual identification of a level 3 stimulus is best for a level 4 stimulus because level 4 is more similar to level 3 than either level 1 or level 7. Similarly, recognition of a level 8 stimulus is best for a level 7 priming stimulus because level 7 is more similar to level 8 than either level 1 or level 4. In subsequent experiments, we attempted to dissociate priming effects from possible compatibility effects.

In Experiment 2, two changes were made: First, the fragmentation levels of studied pictures were changed to levels 2, 4, and 8 so that the fragmentation level of the recognition test could be changed to level 7 (so as to be intermediate between levels 4 and 8). Second, the perceptual identification test was changed from a single level of presentation to our usual ascending method of limits procedure, so that the first level (level 1) was the first stimulus presented in perceptual identification. This made it possible to measure performance based both on overall threshold and on identification of just the level 1 stimulus. Otherwise the procedure of Experiment 2 followed that of Experiment 1.

In Experiment 2, as in Experiment 1, there was no relationship between perceptual identification performance and recognition performance, regardless whether identification was measured by threshold or by level 1 identification. Figure 8 shows these two measures of perceptual identification performance compared with the two measures of recognition performance. As before, all functions are shown as a percentage of range and RTs have been converted to speed measures so that high values mean good performance.

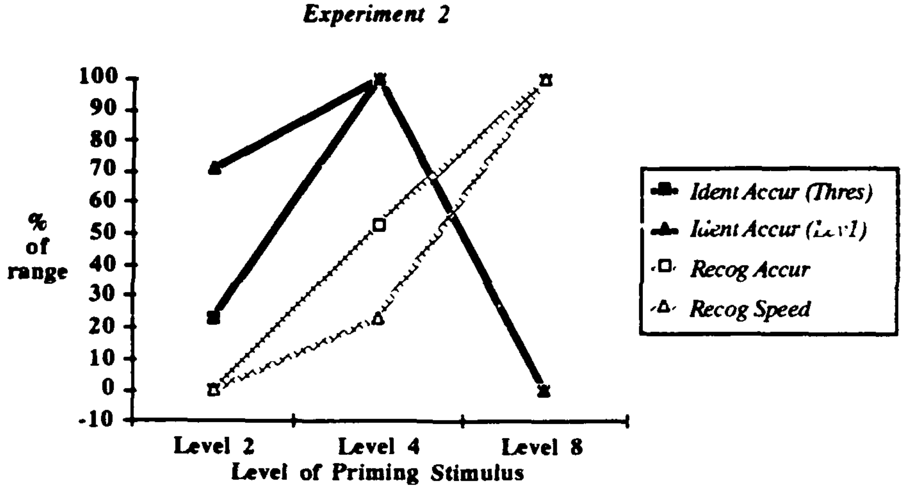

Figure 8. Four measures of performance as a function of priming level for Experiment 2.

In Experiment 2, both measures of perceptual identification show the inverted U-shaped function found previously, and both recognition measures show superiority for the most complete (level 8) priming stimulus. These results cannot so easily be accommodated by the compatibility hypothesis. In identification, the level 2 priming stimulus is more compatible with the level 1 test stimulus, so level 2 should show the best priming when the level 1 identification measure is used under the compatibility hypothesis. Although level 2 shows better relative priming ability with the level 1 identification measure than with the threshold measure, level 4 continues to prime identification best. In recognition, the recognition stimulus, a level 7 stimulus intermediate in value between the level 4 and level 8 priming stimulus, should have been roughly equally compatible to both priming stimuli. Yet in this experiment the level 8 priming stimulus was, if anything, more effective in inducing fast and error-free recognition than the level 7 priming stimulus in Experiment 1 was.

One problem with the RTs obtained in Experiments 1 and 2 was that average recognition RTs were long (typically above 1 second) but the fluency process is presumed to be short. For example, in on-line semantic tasks such as primed or unprimed categorization, average RTs typically never exceed 600 ms. Accordingly, we feared that despite our instructions to respond on the basis of fluency, subjects were engaging in an elaborate and extended retrieval operation in the recognition memory test phase.

In Experiment 3, we made a concerted effort to speed up subjects' recognition memory responses by giving feedback for both speed and accuracy, and by offering a substantial award for best performance. Subjects won points for correct responses, but only if they were faster than 1000 ms and they lost points for errors so as to discourage guessing. The subject with the highest score was awarded a prize of $25.00. Other than the changes in instructions and feedback described above, Experiment 3 was an exact replication of Experiment 2.

Although the instructions had the intended effect of reducing average recognition RTs to below 1000 ms., there was still no relationship between perceptual identification performance and recognition performance. Figure 9 shows perceptual identification performance measured by both thresholds and level 1 identifications compared with recognition performance measured by both errors and speed for Experiment 3, plotted in the same way as previous functions.

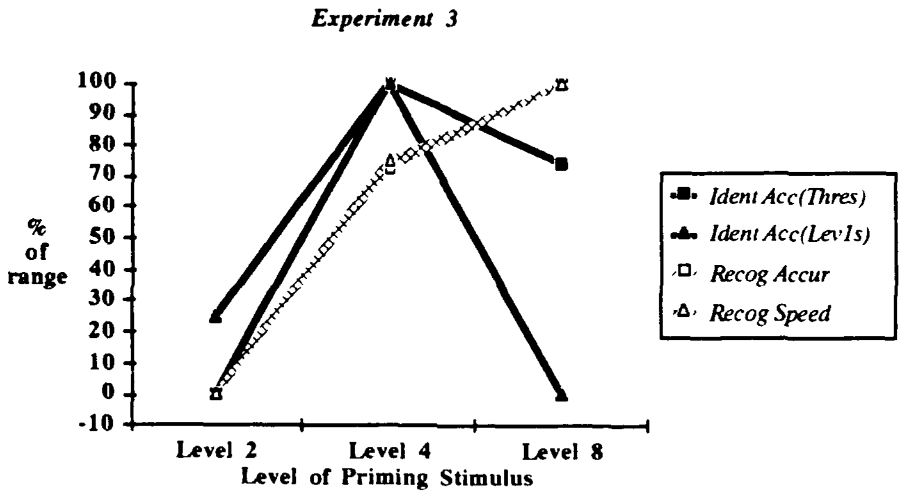

Figure 9 Four measures of performance as a function of priming level for Experiment 3.

In Experiment 3, both perceptual identification measures show the usual inverted U-shaped function we found previously; however, both recognition measures show superiority for the most complete (level 8) priming stimulus. Accordingly, we concluded it was not failure to respond quickly in the recognition test which led to the previous results.

In summary, our research in explicit memory has largely focussed on ways in which effects observed in implicit memory could be shown to be reflected in explicit memory effects -- specifically, in speed and errors in recognition responses based primarily on fluency. Our attempts to do this in continuous recognition memory designs using fragmented test stimuli were fairly successful, although the model based solely on perception speed as a basis for old/new decisions cannot model the RTs quantitatively. The attempts to obtain positive associations between implicit and explicit memory effects when more complete stimuli were used in the recognition test and subjects were encouraged to respond quickly were less successful; to date, we have continued to observe dissociations between implicit and explicit memory effects even though a number of theoretical and empirical results in the literature would suggest that recognition responses can be based on fluency of perception, and hence ought to show positive associations with factors producing fluency in implicit tasks.

Although our next step in this research area is somewhat unclear, one possible direction is to deemphasize the semantics or meaning of the stimulus by using completely unfamiliar and nonmeaningful stimuli such as nonsense figures or nonsense syllables.

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Conference Presentations resulting from this grant

Luo, C. (1991). The functional relationship between the inter item associative strength and the part-set cuing effect in word recall. Paper presented at the annual meeting of the Eastern Psychological Association, New York, NY, April.

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Snodgrass, J. G., & Hirshman, E. (1989). Perceptual learning in the Bruner-Potter (1964) perceptual interference effect. Paper presented at the Twenty-second annual meetings of the Mathematical Psychology Association, Irvine, California, August.

Names of participating professionals

1. Elliot Hirshman, Assistant Professor, Department of Psychology, University of North Carolina at Chapel Hill (consultant, co-author on one or more papers, collaborator)
2. David Fendrich, Assistant Professor, Department of Psychology, Widener University (co-author on one or more papers, collaborator)
3. Kelly Feenan, Graduate Student, doctoral program, Department of Psychology, New York University (collaborator, research assistant, co-author on one or more papers).
4. Chun Luo, Graduate Student, doctoral program, Department of Psychology, New York University (collaborator, research assistant, co-author on one or more papers).
5 Pamela Dalton, Graduate Student, doctoral program, Department of Psychology, New York University (collaborator, research assistant, co-author on one or more papers).
6. Robert Hagen, Graduate Student, MA program, Department of Psychology, New York University (collaborator, research assistant, co-author on one or more papers).
7 Meredith Poster, Graduate Student, MA program, Department of Psychology, New York University (collaborator, research assistant, co-author on one or more papers).
8 Several high school students from Stuyvesant High School have participated in one or another research project as part of their Westinghouse Project. One of the students, Karen Kim, won honorable mention for her experiment on perceptual interference.